Supply chain resilience capabilities in automotive and other industries: a mixed method approach

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Abstract
Purpose – While, supply chain resilience (SCRES) continues to be a dominant topic in both academic and business literature and has gained more attention recently, there is limited knowledge on SCRES capabilities specific to business functions. The purpose of this paper is to identify and investigate capabilities shared between supply, operations and logistics that are most important for SCRES.

Design/methodology/approach – To address this gap, the authors followed a multi-method research approach. First, the authors used the grounded theory method to generate a theoretical framework based on interviews with 51 managers from five companies in automotive SCs. Next, the authors empirically validated the framework using a survey of 340 SC professionals from the manufacturing industry.

Findings – Five significant capabilities emerged from the qualitative study; all were significant in empirical validation. This research advances the knowledge of SCRES as it informs managerial decision-making by identifying capabilities common to supply, logistics and operations that impact SCRES. In addition, the findings of this research help managers better allocate resources among significant capabilities.

Originality/value – This research advances the knowledge of SCRES as it informs managerial decision-making by identifying capabilities common to supply, logistics and operations that impact SCRES. In addition, the findings of this research help managers better allocate resources among significant capabilities.

Keywords Supply chain, Risk management, Supply chain management

Paper type Research paper

1. Introduction
The complexity and global geographic spread of supply chains (SCs), their search for outsourcing and globalization options and the increased volatility of demand have increased the types and frequency of disruptions experienced in SCs. The damaging effects of disruptions, such as natural disasters, pandemics, government regulations and forecasting – or supplier-related issues, can last long if not addressed appropriately and instantly (Pettit et al., 2013). For instance, a fire in a brake supplier facility that supplies parts to Toyota caused a two-week closure of 18 Toyota plants in Japan and US$195m loss in revenues (Tomlin, 2006). Similarly, the failure of a key supplier to provide two critical parts caused Boeing Corporation to lose US$2.6bn (Blackhurst et al., 2005). Recently, the impact of the coronavirus disease 2019 (COVID-19) pandemic on the overall US economy has been estimated to be US$16tn (Powel, 2020). Another example is the semiconductor chip shortage that has crippled the automotive industry, causing a US $110bn loss globally (Naughton, 2021). Companies try to mitigate the impact of SC disruptions by building resilient SCs (Christopher and Peck, 2004; Ponomarov and Holcomb, 2009; Sheffi and Rice, 2005) that have the capability to prepare for unexpected events, respond to disruptions and recover from them by maintaining the continuity of operations.

Some SCs demonstrate higher levels of resilience than others (Christopher and Peck, 2004). Supply chain resilience (SCRES) has been attributed to several antecedents, such as supply management capabilities, information management capabilities, SC orientation, risk management orientation, mitigation processes, visibility, velocity and agility (Ponomarov, 2012; Scholten et al., 2014). However, despite the importance of SCRES as a competitive trait in dynamic and turbulent environments (Eltantawy et al., 2015; Esper et al., 2010; Shore and Venkatachalam, 2003), it is rather surprising that empirical testing of the relationship between SCRES and its antecedents is limited. This research attempts to bridge this gap by investigating the role of strategy (Sebastiao and Golicic, 2008), supply chain...
disruption orientation (SCDO) (Bode et al., 2011) and organizational capabilities (Ponomarov and Holcomb, 2009) in creating and improving SCRES. On the basis of qualitative research and extant literature, we theorize and empirically test a model of SCRES.

Investigating the resilience of an entire SC in one research is an ambitious, if not implausible, endeavor. For the purpose of this research, we focus specifically on capabilities common to supply, operations and logistics that are most relevant for creating or improving SCRES. We have identified these inter-related areas because they comprise the majority of the scope of SC management (CSCMP, 2019), impact customer service and cost dynamics and are essential to SCRES as is it shown in the literature. For instance, supply management has a positive impact on SCRES (Blackhurst et al., 2011) and may constitute up to 45% of the total cost depending on the industry (Jena and Seth, 2016). The continuity of operational processes is the central objective of SCRES (Pettit et al., 2010). In terms of national GDP, around 10% of all expenditures are related to business logistics costs and the impact of logistics capabilities on SCRES is well documented (Ponomarov and Holcomb, 2009).

The current research is grounded in systems theory and the resource-based view (RBV). Similar to other research on different aspects of SCRES (Blackhurst et al., 2011; Brandon-Jones et al., 2014; Munoz and Dunbar, 2015; Salam and Bajaba, 2023), this research relies on these two frameworks that provide complementary perspectives for investigating capabilities and SCRES. The research – with goals to build a conceptual model, to refine the model, to test the model and to provide managerial guidance with respect to SCRES – is conducted in three steps. First, a conceptual model of antecedents and capabilities linked to SCRES is developed on the basis of an extensive review of the literature that points to specific research gaps. Reviewing the literature also helped in developing theoretical sensitivity (Glaser, 1978) in conducting qualitative research. Second, a field study using grounded theory methodology was conducted to investigate the gaps identified during the literature review, specifically to identify SCRES capabilities specific to supply, operations and logistics functions. The field study is conducted within the automotive SC for reasons explained later in Section 3.1 of the manuscript. Moreover, once the capabilities are identified, measurement items related to the capabilities are determined and refined using the insights from the field study. Finally, a survey is administered to empirically test the model and investigate the impact of antecedents and selected capabilities on SCRES in the context of manufacturing firms. Overall, qualitative research was used to develop a substantive theory and quantitative research (involving testing of theoretical model in several manufacturing industries) was used to develop a mid-range theory of SCRES in the automotive and other manufacturing industries.

This research makes three important contributions:

1. It identifies the capabilities common to the inter-related functions of supply, operations and logistics capabilities most relevant to SCRES.
2. It develops a model of SCRES using insights from the literature and the field study and empirically tests the model.
3. It informs managerial decision-making by providing insights into the specific aspects of the identified capabilities most relevant to SCRES.

The paper is structured as follows. Initially, the relevant theoretical background is described, and a conceptual model of SCRES is presented. Subsequently, the results of qualitative research are presented with a focus on integrating the findings into the conceptual model and then the methodology and findings of survey-based qualitative research are presented. Finally, the conclusions, including theoretical and managerial implications and directions for future research, are discussed.

2. Literature Review

In this section, the relevant literature related to systems theory, RBV, SCRES and capabilities in leading logistics and SC management journals is reviewed to develop an initial research model for the research. We also identify the scales available to measure the constructs of interest to determine the constructs for which scales do not exist and need to be developed in the qualitative phase or scales will need to be modified.

2.1 Theoretical background

The current study combines system theory and the RBV. When a disruption occurs in any part of a system, a collection of interconnected, interdependent parts, it is capable of propagating through the system, and the resiliency of the system affects the outcome of that disruption (Zhu and Ruth, 2013). Applying this logic to SCs, it can be argued that a SC is a system of interconnected and interdependent entities involved in products and information flow within and outside firms. Therefore, a systemic view is valuable in understanding SC characteristics (Blackhurst et al., 2005; Blackhurst et al., 2011; Craighead et al., 2020; Munoz and Dunbar, 2015). In systems perspective, resilience is an attribute of systems (Erol et al., 2010). Erol et al. (2010) and Spiegler et al. (2012) used the systems theory framework and the system dynamics perspective to explain firms and SCRES. In this study, we use several tenets of system theory (particularly interdependence and feedback). Interdependence refers to the notion of dependence between systems and subsystems, as SC systems do not exist in isolation. Feedback is the notion that a system can adjust its inputs or processes to improve the outputs. In some ways, a system is self-regulating. These tenets help to explain how SCs operate (Caddy and Helou, 2007) under disruptions and to improve SCRES.

The RBV perspective can be used to understand the relationship between specific resources, capabilities and performance in the context of SCRES. Barney (1991) argued that products and the resources that go into their production impact a firm’s performance. The RBV argues that as a firm succeeds in integrating resources into a specific set of capabilities, it can achieve competitive advantage and higher financial performance (Barney, 1991; Wernerfelt, 1984). Ponomarov and Holcomb (2009) formulated a conceptual framework using the RBV to demonstrate the relationship between logistics capabilities and SCRES. The relationship between organizational mitigation capabilities and resilience was empirically demonstrated by Blackhurst et al. (2011) using the systems theory and the RBV. Similar to Brandon-Jones et al. (2014), we also adopt the RBV to extend the understanding of the relationships between SCRES capabilities and SC performance.
2.2 Defining supply chain resilience

Ever-increasing competition and dynamism in the contemporary business environment and the complex geographical web of supply networks generate disruptions that cause severe financial and reputational impacts for companies (Bakshi and Kleindorfer, 2009; Blackhurst et al., 2005). These impacts range from considerable declines in market value (10%) to a complete collapse in some cases (Tang, 2006a; Xu et al., 2014). In a current study by Gartner, resilience against disruptions was highlighted as a critical concern by the top managers of 87% of firms (Hippold, 2021). To minimize the effect and respond to disruptions, firms are adopting strategies to build resilience (Jüttner and Maklan, 2011; Shin and Park, 2021; Wieland and Wallenburg, 2013). Superior resilience allows SCs to manage disruptions by continuing to deliver to customers where others fail and, thus, to enhance competitiveness (Pettit et al., 2013).

Research on resilience has gained considerable attention. The earliest studies on SCRES started around the 2000s (Christopher and Peck, 2004), which focused on four key principles to create SCRES. Ever since, an increasing number of studies have tried to define SCRES (Jüttner and Maklan, 2011; Ponis and Koronis, 2012; Ponomarov and Holcomb, 2009), outline antecedents and consequences (Blackhurst et al., 2005; Scholten et al., 2014; Zsidisin and Wagner, 2010) and provide practical insights (Blackhurst et al., 2011; Gölgeci and Ponomarov, 2015). SCRES has several definitions, and not surprisingly, many elements are common across definitions, such as proactively preparing for and absorbing the impacts of disruptions, continuing operations of the SC and maintaining control over SC structure and functions during disruptions and restoring to the normal state or improving upon the prior state of the SC after disruptions (Ali et al., 2017; Ponis and Koronis, 2012; Ponomarov and Holcomb, 2009).

We adopt as our working definition the following recent definition by Tukamuhabwa et al. (2015), which builds upon the well-received and oft-cited definitions by Ponomarov and Holcomb (2009, p. 131):

“The adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function.”

2.3 Capabilities linked to supply chain resilience

The extant resilience literature puts forward several capabilities to improve resilience against SC disruptions (Ali et al., 2017; Ambulkar et al., 2015). A capability is defined as “a firm’s capacity to deploy resources […] using organizational processes, to effect a desired end” (Amit and Schoemaker, 1993, p. 35). Numerous authors have provided excellent compilations and syntheses of SCRES capabilities (Ali and Gölgeci, 2019; Ali et al., 2017; Han et al., 2020; Pettit et al., 2010; Pettit et al., 2013). Nonetheless, the trade-offs between capabilities, their relative impacts on SCRES and the optimum selection of capabilities have not yet been clearly understood (Kamalahmadi and Parast, 2016). Particularly, capabilities shared between different functions must be further researched (Ali et al., 2017). On the one hand, there is comprehensive high-level research that includes a wide range of capabilities, and on the other hand, there is research that focuses on only one or a few specific capabilities (Table 1). As an example of the former type of research, Ali et al. (2017) provided a holistic and recent inventory of capabilities linked to SCRES. They also identified five abilities, namely, ability to anticipate, ability to adapt, ability to respond, ability to recover and ability to learn, and related elements for each ability. Overall, they determined 13 elements and 84 element-related business practices. Hohenstein et al. (2015) classified over 30 capabilities and divided those into six broad categories. Han et al. (2020) outlines 11 capabilities addressing readiness, response and recovery phases of SCRES. An example of fine-grained research is a study by Polvyiou et al. (2020) that focused on the role of human resource capability in the resilience of medium-sized companies. Another example is a study by Nikookar and Yanadori (2022), who investigated the importance of the characteristics of SC managers for developing SCRES.

Nevertheless, without empirical validation, which capabilities are the most essential for SCRES is unclear (Stone and Rahimifard, 2018). For instance, Gölgeci and Ponomarov (2013) investigated firm innovativeness and its impact on resilience and validated that higher innovativeness leads to improved resilience; however, as the authors themselves suggested, how can firm innovativeness be used to respond to SC disruptions needs further investigation. Furthermore, Blackhurst et al. (2011) recognized six broad characteristics that either improve or reduce resiliency in the global supplier context without pointing to specific capabilities. Ambulkar et al. (2015) also examined the influence of risk management infrastructure and resource configuration on resilience, but their focus is more on firm resilience than on SCRES. Overall, as reflected in the discussion above and in Table 1, research exists that is either broad and provides a holistic list of capabilities, which makes it difficult to apply in a real-world context, or empirical but too focused, which limits its generalizability. Many of these capabilities are not under the influence of managers with SC and logistics capabilities. Moreover, Pettit et al. (2010) p. 13 assert, “future research must engage a wide range of functional specialists and process integration experts to capture the cross-functional interactions of capabilities”. Overall, there is scope to merge the broad and focused research streams to explore the capabilities common to the most critical functions in SCs, which are also under the direct or indirect influence of those with SC and logistics responsibilities, namely, supply, operations and logistics.

2.4 Conceptual model of supply chain resilience

Due to a dearth of empirically grounded papers in the domain of SCRES, no general or middle-range theories exist. Thus, this research builds on and extends upon the systematic literature reviews of Hohenstein et al. (2015), Tukamuhabwa et al. (2015) and Ali et al. (2017) in the domain of interest. Hohenstein et al. (2015) identified the following top eight elements of SCRES: human resource management, visibility, collaboration, inventory management, redundancy, flexibility, agility and contingency plans. Ali et al. (2017) determined 27 elements while also providing practices that lead to the elements, such as the mapping of SC vulnerabilities for situational awareness. In addition to the 27 elements, they recognized SC network design, anticipation, IT capability, robustness, knowledge management and integration as the mostly cited capabilities in the SCRES literature. Tukamuhabwa et al. (2015) added the following capabilities to the list: logistics capabilities, relational
competencies, velocity and demand management. Whether they are defined as elements or strategies, the long list of capabilities does not include specific capabilities and their relative importance in improving resilience. These results provide a broad framework, but firms, because they have limited resources, can invest in only a limited number of capabilities (Pettit et al., 2013). This study generates a theoretical framework (Figure 1) that integrates the most pronounced capabilities to address this gap.

### 2.5 Supply chain disruption orientation

The concept of SCDO was introduced by Bode et al. (2011, p. 837). In line with their work, it is defined as “a firm’s general awareness and consciousness of, concerns about, seriousness toward, and recognition of opportunity to learn from SC disruptions”. They found that SCDO-oriented firms are more likely to perform better in times of disruptions, and they further affirmed that SCDO firms analyze and assess past disruptions to proactively align their capabilities. Ambulkar et al. (2015) examined the relationship among SCDO, resource reconfiguration and firm resilience. They asserted that SC disruption-oriented firms necessitate the ability to reconfigure resources or have a risk management resource infrastructure to improve resilience. Therefore, we offer the following working proposition (WP):

**WP1.** SCDO is linked to SCRES capabilities.

### 2.6 Supply chain resilience capabilities

As discussed in detailed in an earlier section, there is no research that focuses on capabilities common to the most critical SC functions under the direct or indirect influence of those with SC and logistics responsibilities, namely, supply, operations and logistics. Furthermore, recent literature reviews have revealed that there is a clear need for more empirical research to test the various aspects of SCRES (Kamalahmadi and Parast, 2016; Kochan and Nowicki, 2018). Although this might be due to the initial stages of the topic, more qualitative and quantitative studies are necessary (Blackhurst et al., 2011; Han et al., 2020). Hence, in our conceptual model, we acknowledge the link between SCDO and SCRES capabilities, but we do not populate the box related to capabilities. We offer the following:

**WP2.** Capabilities are linked to SCRES and are unique to the context under investigation.

The empirical qualitative study focused on uncovering the capabilities most salient to SCRES.

### 2.7 Supply chain resilience

Ribeiro and Barbosa-Povoa (2018) provided an overview of the indicators for SCRES in the literature, especially the ones used in modeling papers. They put forward items such as the probability of disruptions, impacts and performance losses (e.g. demand fulfillment). Chowdhury and Quaddus (2017) developed measurement items for SCRES as time to react, time to return to normal conditions, the impact of disruptions and the frequency of disruptions. In line with the literature, we adopt time to react, time to return to normal conditions, the impact of disruptions and the frequency of disruptions as the outcomes of SCRES.

### 2.8 Supply chain resilience outcomes

SC performance is fundamentally viewed as the ability of a SC to maintain product availability and deliver on time to meet the requirements of customers (Gunasekaran et al., 2004). The

### Table 1: Overview of the relevant SCRES literature

<table>
<thead>
<tr>
<th>Study</th>
<th>Type of research</th>
<th>Capabilities identified and/or investigated</th>
<th>Findings and limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hohenstein et al.</td>
<td>Literature review</td>
<td>Six ex-ante disruption phase (collaboration, human resource management, inventory management, predefined contingency plans, redundancy, visibility), five post-disruption phase (agility, collaboration, flexibility, human resource management, redundancy) capabilities</td>
<td>Capabilities improve SCRES. Broad holistic scope. Not considered the connections between overlapping capabilities. Consider cross-functional teams (to be established by human resource management).</td>
</tr>
<tr>
<td>Polyviou et al. 2020</td>
<td>Empirical paper</td>
<td>Identified social capital as a resilience supporting resource for medium-sized manufacturing firms in the USA</td>
<td>Human resource capability impacts resilience on mid-sized companies. Limited scope, not considering functions.</td>
</tr>
<tr>
<td>Ali et al. 2017</td>
<td>Literature review</td>
<td>Five main SCRES capabilities with 13 elements and 84 managerial practices, divided in pre-, during- and postdisruption phases</td>
<td>Broad holistic perspective, not considering different functions in SCM.</td>
</tr>
<tr>
<td>Tukamuhabwa et al.</td>
<td>Literature review</td>
<td>18 proactive SCRES strategies, 11 reactive SCRES strategies</td>
<td>Broad focus, not considering functions.</td>
</tr>
<tr>
<td>Kochan &amp; Nowicki</td>
<td>Literature review</td>
<td>5 SC capabilities for responsiveness, 8 SC capabilities for anticipation and 2 SC capabilities for recovery</td>
<td>Broad scope, not considering functions.</td>
</tr>
<tr>
<td>Jüttner &amp; Maklan 2011</td>
<td>Research paper</td>
<td>Explore the relationship between SCRES, SCRM and supply chain vulnerability in the context of a global financial crisis</td>
<td>Narrow focus, not considering functions.</td>
</tr>
<tr>
<td>Pettit et al. 2010</td>
<td>Research paper</td>
<td>Identified 14 SCRES capabilities with 71 subfactors, and 40 specific vulnerability factors that are grouped in 7 categories</td>
<td>Broad focus, not considering functions.</td>
</tr>
</tbody>
</table>

*Source: Authors’ own work*
literature on SC performance can be grouped into the following six major categories: cost reduction (Wang et al., 2011); quality improvement in product and service fulfillment (Shepherd and Günter, 2011); process time reduction including lead, cycle and delivery times (Wang et al., 2011); process improvement for capacity and resource utilization (Gunasekaran et al., 2004); flexibility such as response to customer demands and environmental changes (Gunasekaran et al., 2004); and innovativeness (Wang et al., 2011).

The extant literature argues that by returning to a normal state or an improved state more quickly than their competitors, companies can increase competitiveness (Pettit et al., 2013). Blackhurst et al. (2011) contended that firms that anticipate and respond to disruptions succeed in a faster recovery process, whereas slow recovery times negatively influence customer perceptions and relations and have enduring impacts (Sheffi and Rice, 2005). A firm may realize performance benefits from SCRES by continuing to serve its customers and operate during and after a disruption, which may also involve enlarging its market share by improving competitiveness (Carvalho et al., 2012; Lee et al., 2016). Quicker recovery times lead to improved performance by delivering better customer performance and increased sales. Therefore, we offer the following:

WP3: SCRES impacts SC outcomes.

2.9 Summary of research gaps
Research on SCRES has made significant progress in recent years. However, several gaps remain. First, the literature, for the most part, is either broad and comprehensive (Ali and Gölgeci, 2019; Han et al., 2020; Hohenstein et al., 2015; Pettit et al., 2010; Pettit et al., 2013) or too narrow (Nikookar and Yanadori, 2022; Polyviou et al., 2020). However, a focus on identifying the relative impacts of capabilities and empirically formulating an optimal portfolio is missing (Dittfeld et al., 2022; Zhao et al., 2023). Without empirical validation, it is difficult to identify and assess specific capabilities that are most essential for SCRES in unique contexts. Second, while there is an understanding that SCDO affects SCRES, but how and which capabilities common to supply, logistics and operations are most affected by SCDO are unclear. Third, SCRES capabilities affect SCRES outcomes and financial outcomes. Nevertheless, the measurement of SCRES and financial outcomes needs further research. To address these limitations of the extant literature, the primary intent of the qualitative study is to investigate the middle black box (Figure 1) to discover the capabilities common to supply, logistics and operations related to SCRES and to identify, adapt or develop appropriate scales. The secondary intent is to uncover ways in which SCRES outcomes and financial outcomes could be captured and then operationalized for empirical quantitative research.

3. Methodology
In the inaugural issue of the Journal of Mixed Methods Research, Tashakkori and Creswell (2007) say:

We have broadly defined mixed methods here as research in which the investigator collects and analyzes data, integrates the findings, and draws inferences using both qualitative and quantitative approaches or methods in a single study or a program of inquiry (p. 4).

In this research, we use qualitative research (specifically the grounded theory methodology) and quantitative research (specifically survey methodology) to provide better results by integrating the findings from two different methods (McGrath, 1982). Golicic and Davis (2012) call for more research in the field of SC management using mixed methods research. The integration provides results that either quantitative or qualitative research could not provide in isolation. Similar to recent studies in the discipline of logistics and SC management (Song et al., 2022; Viale et al., 2022), we sequentially implement the two methods. The results from the first study (using grounded theory) are used to develop the second study (using survey), thereby providing deeper insights into the research problem. Furthermore, the two methodologies bring in unique strengths. Grounded theory provides the tools to delve deep into managerial perceptions to provide rich descriptions of capabilities and hence maximum context. Quantitative research provides results...
that are generalizable to the population of interest and hence maximum generalizability of actors (McGrath, 1982). As suggested by Golicic and Davis (2012), the results are reported separately for each study and the results of the two studies are integrated in the discussion and theoretical and managerial contributions sections.

3.1 Study 1: qualitative research and theoretical model
For the first part of the research, a qualitative approach using grounded theory methodology (Glaser, 1978; Glaser and Strauss, 1967) was used to develop an in-depth understanding of capabilities common to supply, operations and logistics functions that contribute to improved SCRES. Grounded theory allows us to better understand human interactions, relations, underlying meanings and organizational settings. As we dealt with the complex phenomenon of SCRES, grounded theory was an appropriate method to explore the underlying phenomenon (Mello et al., 2008; Randall and Mello, 2012) and to help fill the gaps in developing the theoretical framework (Fischer and Ottes, 2006; Mello et al., 2008) as SCRES.

Our qualitative study focused on manufacturing firms in the SCs of the automotive industry because this industry is mature and forward-thinking and expected to be taking steps in developing the field of SCRES. All the functional areas of interest in this research, namely, supply, operations and logistics, are critical to the companies of this industry, especially in times of SC disruptions. We selected the companies because they have global SCs.

Semi-structured interviews following the McCracken (1988) guidelines for conducting interviews were the primary data source for this part of our study. In addition to the predetermined questions, these interviews allowed us to ask follow-up questions and to request examples and delve into the phenomena of interest. The number and content of in-depth interviews were based on the concept of “theoretical sampling” (Glaser and Strauss, 1967; Mello and Flint, 2009). We conducted 51 interviews with the executives of five companies. The interviews were conducted face-to-face and transcribed and usually lasted approximately 45–60 min. The initial set of interview partners was selected on the basis of their experience with SC disruptions, job profile and responsibility level. In addition, the interviews were conducted in batches to allow for constant comparison, to let the theory to emerge, to inform further data collection and the choice of the interviewees and to pursue theoretical saturation (Strauss and Corbin, 1998). As the interviews progressed, we selected additional participants to enable further exploration of new categories and concepts that emerged.

The initial and iterative coding of 51 interviews resulted in over 1,000 open codes. Subsequent analysis and coding led to abstraction into 52 higher-level codes relevant to this research. We coded specifically for phrases that represented capabilities and linked concepts. For example, open codes of employee competence and employee experience were grouped into selecting employees. This was later determined to be a human resource capability. Once the 52 codes were placed into different capabilities, we then looked at the frequency and importance of each code linked to the emergent capabilities. Five emerged as being most relevant. These are discussed in Section 3.1.1 Emergence of Capabilities from Interviews.

The interview protocol evolved, and we continued the interviews until theoretical saturation was achieved; that is, the comparative analysis did not yield additional explanatory power for a category, the properties of a category or relationships among categories (Duchescher and Morgan, 2004; Glaser, 2001). See Appendix 1 for an overview of participating companies. Figure 2 shows how the firms fit into the automotive SC, the number of managers interviewed and the roles of managers who participated in the research.

As the intention was to discover the capabilities common to supply, operations and logistics, subsequent interviews were increasingly focused and directed to uncover the capabilities of interests (Manuj et al., 2014; Mello and Flint, 2009; Randall and Mello, 2012; Strauss and Corbin, 1998). Tables 1 and 2 suggest that our sample is varied and inclusive: the participants mentioned the majority of the seven vulnerability factors and 40 sub-factors, as identified in a comprehensive study by Pettit et al. (2010).

3.1.1 Emergence of capabilities from interviews
As we began the study, anecdotal evidence suggested that firms were struggling to link capabilities with resilience outcomes. Specifically, the firms seemed to lack insights into how to align capabilities with SC disruptions. The following capabilities emerged as those common to supply, operations and logistics: process, communication and coordination, human resource, collaboration and information technology capabilities. Appendix 2 provides power and proof quotes (Fawcett et al., 2014) sample quotes that support the identification of capabilities and links to resilience outcomes and other constructs included in the quantitative study. The following discussion draws upon the interviews with the participants.

**Process capability** is defined as the ability of a process to generate outputs within customer expectations and within the required specification limits, close to the target value (Seebacher and Winkler, 2015). Process capability with respect to SCRES in the automotive industry is a combination of activities undertaken to enable a predecided or ad hoc set of steps to deal with changes caused by disruptions; as Sebastian from AutoMan describes:

> Your process needs to be clearly standardized and if you have deviations, you need to react to them. If they have no standards or clear rules, you cannot organize any deviation management.

That is, process capability allows a plan to be executed. We found that process capability is particularly critical for the automotive industry because automotive SCs are complex and multi-tiered, involving a wide range of activities such as sourcing raw materials, manufacturing components and assembling vehicles. Disruptions can occur at any of these numerous nodes or links in the SC and propagate through the system. Furthermore, one of the differentiating characteristics of the industry is that typically a company manufactures a variety of products ranging from small, fuel-efficient cars to large trucks and buses. Process capabilities enable flexibility and adaptability to be able to respond to disruptions in supply, logistics and operations.

**Communication and coordination capability** allows companies to communicate internally and to share information and ideas within the organization, and to communicate externally with SC partners. Furthermore, it is the ability to share information
and ideas with key customers and suppliers, establish personal and long-term relationships, share common processes and invest in knowledge transfer, such as infrastructure; all these impact resilience and financial outcomes. A typical automotive SC engages thousands of entities. Therefore, effective communication and coordination are essential for ensuring that the right materials are delivered to the right place at the right time and that any issues or problems are quickly identified and resolved; as Hubert from AutoTechSupplier states, “There is good cooperation with the suppliers and they react very well, even proactively. They give information if there are deviations.”

Superior communication and coordination allows companies to share information with a large number of suppliers, logistics providers and other partners in the SC to improve visibility, which in turn enables responsiveness during times of disruption.

**Human resource capability** is defined as the ability of an organization to recruit, maintain and develop its human resources (Gibson and Cook, 2001). Major importance of this capability is due to the knowledge, skills and abilities of employees, including their training (Gammelgaard and Larson, 2001). Human resource abilities, such as experience and a good fit with the corporate culture, contribute to better decision-making and influence financial and operational outcomes. Automotive industry is unique that it is highly regulated in the way it operates and has to constantly innovate. Recent technological advances in areas such as engine efficiency, safety features, alternative energy sources and integration of Internet of Things with vehicles make knowledge a key component in the way automotive companies compete. In our interviews, managers stressed the need for both experienced employees and newer employees to gain experience during times of crises, making retention important for automotive SCs. Gerald from AutoTechSupplier emphasized, “Experience has helped us well through the crisis”. Developing human resource capability through training

<table>
<thead>
<tr>
<th>Participant information</th>
<th>n (340)</th>
<th>%</th>
</tr>
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<tbody>
<tr>
<td><strong>Job title</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Member of Management Board</td>
<td>30</td>
<td>9</td>
</tr>
<tr>
<td>Senior Management</td>
<td>40</td>
<td>12</td>
</tr>
<tr>
<td>Middle Management</td>
<td>65</td>
<td>19</td>
</tr>
<tr>
<td>Supervisor</td>
<td>99</td>
<td>29</td>
</tr>
<tr>
<td>Manager</td>
<td>106</td>
<td>31</td>
</tr>
<tr>
<td><strong>Firm size</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than 250 employees</td>
<td>112</td>
<td>33</td>
</tr>
<tr>
<td>Between 251 and 500 employees</td>
<td>91</td>
<td>27</td>
</tr>
<tr>
<td>Between 501 and 1,000 employees</td>
<td>55</td>
<td>16</td>
</tr>
<tr>
<td>Greater than 1001 employees</td>
<td>82</td>
<td>24</td>
</tr>
<tr>
<td><strong>Annual revenue</strong></td>
<td></td>
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<tr>
<td>Less than 10 million</td>
<td>159</td>
<td>47</td>
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<tr>
<td>10–100 million</td>
<td>80</td>
<td>23</td>
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<tr>
<td>101–200 million</td>
<td>62</td>
<td>18</td>
</tr>
<tr>
<td>Greater than 200 million</td>
<td>38</td>
<td>11</td>
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<tr>
<td><strong>Experience in SCM</strong></td>
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<tr>
<td>1–5</td>
<td>152</td>
<td>45</td>
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<tr>
<td>6–10</td>
<td>117</td>
<td>34</td>
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<tr>
<td>11–15</td>
<td>38</td>
<td>11</td>
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<tr>
<td>Greater than 16 years</td>
<td>33</td>
<td>10</td>
</tr>
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</table>

*Source: Authors’ own work*
and development programs ensures employees have the skills and knowledge needed to effectively manage and operate SCs (particularly during times of disruption) and can grow and succeed in their organization.

Collaboration capability is defined as the ability of an organization to join efforts and work effectively with other SC partners for mutual benefits. In the context of resilience, this capability is developed by approaching issues jointly with suppliers, treating one another fairly in dealings and making cooperative changes as needed. As mentioned earlier, automotive SCs are complex in terms of nodes, links and partnerships. Collaboration helps to develop logistics and transportation networks that reduce delivery times and costs or to develop new products and technologies in the usual course of business. However, collaboration is particularly important in times of crises as it allows a firm to leverage the capabilities of its suppliers, logistics providers and other partners in the SC to respond to disruptions effectively and quickly. Collaboration ensures that supply, logistics and operations activities are coordinated and that any issues or problems are quickly identified and resolved. Stefan from AutoTechSupplier describes that collaboration by stating, “What is extremely important is flexibility. That means short distances, always the same people, unbureaucratic communication, telephone, mail and technical service”.

Information technology capability is defined as an organizational capability that enables companies to mobilize and deploy resources on the basis of information technology in combination with other resources and capabilities. IT capability contributes to timely and accurate decision-making and influences both financial and operational outcomes. Because of the complexity of automotive SCs, very large amounts of data are generated and captured at different points in the SC. IT capability plays a critical role in the automotive industry by enabling companies to manage and analyze large amounts of data and to automate and optimize SC processes. This helps companies to improve the visibility and responsiveness of SC, which is essential to respond to disruptions. This visibility supports firms in integrating the relevant people as Albert from VehicleMan describes, Information has to be given down to people, so they can recognize a disturbance early on and know what to do.

In addition to the initial purpose of discovering the capabilities common to supply, operations and logistics, we made two additional discoveries. The first is the identification of the specific properties of capabilities that are most relevant to SCRES. This finding is used to fine-tune the items in the quantitative section. The second is the identification of an additional construct, namely, the strategic focus of organizations, which impacts SCDO.

3.1.2 Emergence of strategic focus
Strategic focus emerged in the qualitative study as a construct that impacts SCDO. One participant said, “Two objectives are very important for me: First: Adhere to your goals. And focusing on your strategy”. Later they added, “What I meant when I was talking about adhering to your goals - the lasting reliance on your strategy even in the crisis”. The SC strategy of an organization is the collection of objectives set for the SC and the policies and choices executed to support them. SC strategy can be viewed as an umbrella for operations strategy (Perez-Franco et al., 2016). Accordingly, the strategic focus deals with the level of analysis, whether strategic, operational or tactical (Gunasekaran et al., 2001), and allocates resources for either efficiency or responsiveness. We build upon insights from qualitative research (see Appendix 3 for supporting quotes) and Sebastiao and Golicic (2008) to define strategic focus as concentrating decisions and directing efforts in a SC to balance cost and customer service outcomes. Focus on customer service and related outcomes is more likely to lead to high resilience than on cost-focused outcomes.

3.1.3 Theoretical model and hypotheses
Figure 3 presents the final model that emerged from the literature and qualitative research.

Based on the qualitative research, one new construct was incorporated into the initial SCRES framework (Figure 1) and testable hypotheses were developed from the WPs. As discussed earlier, insights from qualitative research suggested that strategic focus in terms of balance cost and customer service outcomes impacted SCDO. Strategic focus is similar to efficiency versus responsiveness as explained by Fisher (1997), who focuses primarily on the demand characteristics of the SC and the Lee (2002) framework that classifies SCs into efficient, responsive, risk-hedging and agile based on both supply and demand characteristics. SCs focusing more on customer service outcomes are more likely to invest in mechanisms to counter and reduce uncertainties to increase responsiveness whereas those focusing more on cost outcomes are likely to focus on productivity and lean measures to increase efficiency (Ivanov et al., 2014). This proposition also addresses the call for further research on strategies to mitigate disruptions (Tang, 2006b). Therefore, based on insights from the qualitative research and building upon extant literature (Fisher, 1997; Lee, 2002; Sebastiao and Golicic, 2008; Tang, 2006a; Wu et al., 2014), we hypothesize:

H1. Strategic focus on customer service outcomes is positively related to SCDO.

SC disruption-oriented firms tend to reconfigure resources to improve resilience. It can be inferred that firms high in SCDO are more likely to act and consequently invest in the capabilities that increase SCRES in their specific context (Bode et al., 2011). Therefore, building upon WP1 and extant literature linking SCDO to resilience capabilities (Ambulkar et al., 2015; Yu et al., 2019; Hussain et al., 2023), and evidence from the qualitative research, we propose the following set of hypotheses (H2–H6). There is evidence linking SCDO or aspects of SCDO with each of the six capabilities. In the specific context of the automotive industry, SCDO will positively impact each one of the six capabilities that emerged in the qualitative research. Firms with high SCDO focus more on being aware of disruptions and use SC disruptions as opportunities to learn (Bode et al., 2011).

Blecken (2010) and Scholten and Schilder (2015) found that SCDO is linked with better process capability. This stems from implementing continuous improvements, which strengthens risk awareness, SC (re-)engineering and knowledge management – aligning with recommendations from SC literature. The following quote by Georg (AutoManPartner)
from our qualitative study reinforces this relationship, “I have learned that processes work well when the interfaces are clearly defined, and those responsible are named”. In sum, SCs that are more aware of disruptions and use SC disruptions as opportunities to learn will invest in processes capability to enhance resilience. Therefore, we propose:

**H2.** SCDO is positively related to process capability.

Saglam *et al.* (2022) found that SC orientation is linked with better communication capability. This is because effective and frequent communication among SC partners increases the likelihood of anticipating or promptly responding to unforeseen disruptions and challenges. The following quote from our qualitative study also reinforces this relationship, “There is good cooperation with the suppliers and they react very well, even proactively. They give information if there are deviations” (Hubert, AutoPartsSupplier). Collaboration and communication capability facilitate a swift recovery in the aftermath of difficulties through their joint efforts. In sum, SCs that are more aware of disruptions and use SC disruptions as opportunities will invest in communication and coordination to augment visibility and connectivity to improve resilience. Therefore, we propose:

**H3.** SCDO is positively related to communication and coordination capability.

Scholten and Schilder (2015) found that SCDO is linked with collaboration capability. This is because as companies actively participate in activities such as information-sharing, collaborative communication, joint relationship efforts and mutual knowledge creation, there is a corresponding increase in the awareness of the SC. This ultimately culminates in the development of a more resilient SC. The following quote from our qualitative study also reinforces this relationship, “And the connections I have […] He [the supplier] tells me things that don’t come out until 3–4 weeks later, even if it is often bad news” (Samuel, AutoPartsSupplier). In sum, SCs are more tuned to disruptions, and wanting to learn from them will encourage them to invest in collaborative efforts to make the SC more resilient.

**H4.** SCDO is positively related to collaboration capability.

Companies with a focus on SCDO aim to learn from their past SC disruption experiences and proactively build capabilities that enable them to respond effectively to future disruptions (Ambulkar *et al.*, 2015). Polyviou *et al.* (2020) and Scholten *et al.* (2020) found that SCDO is linked with better human capability. This is because, in those companies, the employees dedicate themselves to a state of readiness and develop a degree of alertness to disruptions within the SC. The following quote from our qualitative study also reinforces this relationship, “Throw yourself early into the cold water. Be there with small events. Learn from the experienced” (Zacharias, AutoMan). Firms focused on maintaining awareness toward and learning from disruptions are likely to invest in human resources to enable higher resilience. Therefore, we propose:

**H5.** SCDO is positively related to human resource capability.

Liu and Wei (2022) found that SCDO is linked with better information technology capability. This is due to the fact that information technology capability plays a crucial role in processing, organizing, visualizing and analyzing information sourced both internally and externally. This capability enables effective decision-making for SCRES, particularly in the face of SC disruptions. The following quote from our qualitative study reinforces this relationship, “Information has to be given down to people, so they can recognize a disturbance early on and know what to do?” (Albert, VehicleMan). Firms with
awareness of and interest in leveraging learning from disruptions can leverage IT capabilities for the identification, assessment, mitigation and monitoring of risks; organizations can expedite the restoration of normal operations, as highlighted by Ivanov et al. (2021). Therefore, we propose:

**H6.** SCDO is positively related to information technology capability.

Process capability serves as a foundation upon which resilient SCs are built. By assessing processes within a SC, organizations can identify potential bottlenecks, and vulnerabilities and address them accordingly (Scholten et al., 2014). This proactive approach would increase their understanding of the network, enable them to make informed decisions and reduce variability, thereby enhancing their ability to respond quickly and effectively to disruptions, as highlighted by Marley et al. (2014). When disruptions occur, organizations with well-defined and capable processes can more readily adjust their operations to accommodate changes in SC, such as shifting production lines or sourcing materials from alternative suppliers.

Therefore, building upon WP2 and extant literature linking process capability to SCRES, and evidence from qualitative research, we propose:

**H7.** Process capability is positively related to SCRES.

Communication and coordination capability is linked to SCRES (Ali et al., 2017) as it increases the ability to respond to SC disruptions through coordinated response activities (Scholten et al., 2014). Communication and coordination help firms to increase SC visibility and information exchange, which is turn helps to faster and better respond to disruptions by achieving agility (Christopher and Peck, 2004; Jüttner and Maklan, 2011). Accordingly, drawing on WP2, established literature that associates communication and coordination capability with SCRES, as well as findings from our qualitative research, we advance the following hypothesis:

**H8.** Communication and coordination capability is positively related to SCRES.

Collaboration capability is the capacity to coordinate the response to SC disruptions by collaborative planning with partners (Christopher and Peck, 2004) and information- and intelligence-sharing (Jüttner and Maklan, 2011; Pettit et al., 2013) and to coordinate immediate response (Scholten et al., 2014). There is evidence that vertical and horizontal collaboration between SC partners increases SCRES (Leat and Revoredo-Giha, 2013). In light of WP2 and existing literature linking collaboration capability to SCRES, as well as qualitative study findings, we propose **H9:** Collaboration capability is positively related to SCRES.

Human-oriented capabilities, like many other SC capabilities, are crucial for SCRES (Adobor, 2019; Ali et al., 2017; Gu et al., 2023; Saeed et al., 2022). Human skills are recognized as non-physical strategic assets that are difficult for competitors to imitate. Human resource capabilities can help determine what is the most important SC strategy (Hohenstein et al., 2014). SCRES is rooted in knowledge management and a comprehensive understanding of both SC and human resource structures (Blackhurst et al., 2011; Pettit et al., 2013; Scholten et al., 2014). SCRES can thus be enhanced through targeted education and training initiatives (Jüttner and Maklan, 2011). Establishing a SCRES culture further strengthens SCRES (Christopher and Peck, 2004). The implementation of SC exercises, simulations and trainings additionally contributes to increasing SCRES (Rice and Caniato, 2003). Building on WP2 and the existing literature linking human resource capabilities and SCRES, as well as the findings from qualitative research, we therefore propose:

**H10.** Human resource capability is positively related to SCRES.

Companies use IT to communicate information and knowledge across corporate functions and boundaries. Furthermore, it enhances sensing and information processing skills so that firms may respond quickly to unexpected disruptions and effectively compete in a dynamic environment (Ngai et al., 2011). Consequently, informed by WP2, existing academic works connecting IT capability with SCRES, and insights gleaned from our qualitative research, we put forth the following hypothesis:

**H11.** Information technology capability is positively related to SCRES.

SC operations cannot continue and customer demands cannot be met unless there is a continuous flow of products and services. A firm may realize performance benefits from SCRES by continuing to serve its customers and operate during and after a disruption. Quicker recovery times lead to improved SC performance by delivering better customer performance and increased sales (Gu et al., 2021). Extant literature provides extensive support for the relationship between SCRES and SC outcomes including efficiency and security (Stadtfeld and Gruchmann, 2023) and significant indirect effect of SCRES on firm performance (Salam and Bajaba, 2023). Wong et al. (2020) found SCRES to be positively associated with risk management, market and financial performance. In the qualitative research, within the specific context of the automotive industry, several SC performance outcomes were mentioned by the participants as being affected by SCRES such as relational capital, trust and communication. Therefore, building upon WP2 and extant literature linking SCRES to SC outcomes, and evidence from qualitative research, we propose:

**H12.** Supply chain resilience is positively related to SC performance.

### 3.2 Study 2: quantitative research

For the second part of the research, a quantitative approach using survey methodology was followed. To empirically test the research model, we used, developed or modified scales for strategic focus, SCDO, process, communication and coordination, collaboration, human resources and IT capabilities, SCRES and financial outcomes.

We did not find any existing scales for strategic focus, a key concept that emerged in the qualitative research. Therefore, we built upon existing ideas from literature and insights from the interviews to develop the scale (Froehle and Roth, 2004; Roth et al., 2008). In line with the Churchill (1979) procedure, we first examined the literature to understand how the domain of each construct was defined by other researchers and to identify...
present scales. The concept of strategic focus is similar to existing concepts such as SC strategy (Fisher, 1997; Lee, 2002; Sebastiao and Golicic, 2008). Next, similar to Pervan et al. (2009), interviews were used to refine the construct and associated items. The use of qualitative studies to generate and/or refine scale items is an established method where there are no available items (Ali et al., 2018; Chowdhury and Quaddus, 2017). At every stage, the findings were validated with relevant literature, as suggested by Fawcett et al. (2014).

Statements from participants that reflected the concept under investigation were analyzed and keywords were examined. Main keywords for strategic focus included efficiency, brand name and targeting of markets. Interviews revealed a focus on customer and customer service and related outcomes is more likely to lead to high resilience than on cost-focused outcomes. We found all three keywords had been mentioned in a firm or SC strategy context in the literature (Gu et al., 2021), even though the term strategic focus was not always used. Major keywords for human resources included employee experience, employee training and mutual trust. Interviews revealed a higher focus on these keywords was likely to lead to high resilience. We found all three keywords had been mentioned in a firm or SC context in the literature (Chunsheng et al., 2020); however, the specific focus on disruption was relatively novel. Major keywords for information technology included internal systems, supply side systems and customer side systems. Interviews revealed a higher focus on these keywords in the context of quick response time during disruption would likely lead to higher SCRES. We found all three keywords had been mentioned in a firm or SC context in the literature (Scholten and Schilder, 2015); however, the specific focus on disruption was relatively novel.

Once the keywords were identified, they were developed into statements in the context as meant by the participants and using their language as much as possible. Finally, the face validity of the items for the emerged constructs was ensured by conducting interviews with academic colleagues and doctoral students with business experience (Froehle and Roth, 2004). Based on the feedback, the wording of the items was refined and finalized and if needed, problematic items were dropped (Roth et al., 2008). Finally, as explained in detail later, robust statistical analysis and data ensures that we had a valid scale for measuring the construct of interest (Hair et al., 2006).

The scales for human resource capability were developed by merging the findings from our qualitative study with extant literature, similar to the process we followed for strategic focus. The rest of the constructs had established scales. In some cases, we made minor adaptations/additions based on the insights from the qualitative study.

For the SCDO construct, we adopted the scale by Bode et al. (2011) and captured the general awareness and seriousness of the firms toward disruptions. To measure process capability, measures from Srinivasan and Swink (2018) were used. The communication and coordination capability was measured by adopting the scales from and Chen and Pua (2004) and Wieland and Wallenburg (2013) and Gligor and Holcomb (2012). The collaboration capability was measured using the scales originally developed by Fawcett et al. (2011) and Scholten and Schilder (2015) and by capturing joint relationship efforts and seamless information exchange. The human resource capability was measured by merging the findings from our qualitative study, Polyviou et al. (2020) and Fischer and Pollock (2004). The scale by Fawcett et al. (2011) was adapted to measure IT capability.

Hohenstein et al. (2015) contended that the majority of the resilience literature is qualitative and that there is a need for measuring resilience. As one of the few examples, Chowdhury and Quaddus (2017) took a multi-dimensional approach to capture readiness, reserve capacity, response times, reduction of impact and recovery cost. We followed the conceptualization of Chowdhury and Quaddus (2017) to measure SCRES. Finally, for SC performance, we adopted the scale by Gunasekaran et al. (2004) and Shepherd and Günter (2011) and captured on-time delivery, cost, customer satisfaction and net income. Please see Appendix 3 for all items.

3.2.1 Survey development
The initial phase for scale development was the qualitative study. The findings of this study were compared and validated with the relevant literature. Thereafter, the item generation and sorting phases were conducted. After developing an initial version, we pretested the survey. Following an analysis of results from a pilot test involving 100 participants, we decided to retain the original wording of each scale. An ordered progression of factor analysis (Anderson and Gerbing, 1988) was also conducted to determine the structure of items and the proposal of the measurement model. Finally, we validated the internal structure of the survey with confirmatory factor analysis (CFA).

We used Amazon Mechanical Turk (AMT) to find a suitable sample. Research suggests that AMT platform respondents are comparable to traditional survey respondents (Buhrmester et al., 2011), and recent studies have used AMT to recruit participants with work experience in SC, logistics and operations management (Zhu et al., 2018). Our sample population comprised professionals from operations, logistics and SC management functional areas in manufacturing firms. As our qualitative study spanned multiple tiers of manufacturers in the automotive SC and a subset of these manufacturers serve multiple industries, we expected the results to hold in a wider manufacturing context. We followed the techniques proposed by Schoenherr et al. (2015) to achieve better responses. The participants selected an option to specify whether they agree or disagree with statements regarding the SC capabilities of their companies and the impact of capabilities on resilience based on a Likert scale from 1 to 5.

We asked filtering questions to screen the participants to determine those who occupy the following positions: Member of the management/executive board, senior director, senior manager, supervisor or manager. The participants were further filtered with questions if their functional area is either logistics, operations or SC management. The survey was terminated if the participants did not satisfy the aforementioned criteria. Furthermore, we accepted only one response per IP address. After completing the given task, the respondents received monetary compensation. After the screening process, such as removing straight line responses, 340 participants were able to complete the survey out of 1,709 attempts in total. Table 2 and Appendix 4 provide the sample demographics and descriptive statistics.

3.2.2 Data analysis
To evaluate the measurement model, we first looked at Cronbach’s alphas for reliability, which was above 0.7 for all the constructs. Next, a CFA using maximum likelihood estimation was also
conducted to evaluate and validate the constructs (Anderson and Gerbing, 1988), and a measurement model was developed to ensure composite reliability. Finally, all the hypotheses were tested using a structural equation model using AMOS 27.

On the basis of the EFA, out of 60 items, 29 items with low factor loadings (below 0.6) and cross-loadings were removed; thus, 31 items remained, which loaded onto nine factors (Table 3).

According to the CFA results, the nine-factor model was found to have a good fit with the following absolute and incremental fit indices (IFI = 0.95; CFI = 0.95; RMSEA = 0.04). Fit indices establish a good fit between the data and the measurement model. To assess the discriminant and convergent validity and composite reliability, we calculated the average variance extracted (AVE) and the composite reliability (CR) with the CFA results (Anderson and Gerbing, 1988; Bagozzi and Yi, 1988; Fornell and Larcker, 1981; Henseler et al., 2015). All the factor loadings were above 0.7 (except for one item at 0.68) Table 4 displays the results for Cronbach’s alpha scores, CR and AVEs. These values all together provide sufficient ground for a good model fit, discriminant and construct validities and internal consistency (Hair et al., 2014).

Table 3  Item loadings

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<th>Label</th>
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<th>2</th>
<th>3</th>
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<tbody>
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<td></td>
<td>SF2</td>
<td>0.814</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SF3</td>
<td>0.872</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>9. Human resource capability</td>
<td>Hum1</td>
<td>0.843</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Hum2</td>
<td>0.748</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Hum3</td>
<td>0.858</td>
<td></td>
<td></td>
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<tr>
<td>Cronbach’s alpha</td>
<td>0.880</td>
<td>0.819</td>
<td>0.759</td>
<td>0.811</td>
<td>0.868</td>
<td>0.773</td>
<td>0.744</td>
<td>0.769</td>
<td>0.752</td>
<td></td>
</tr>
</tbody>
</table>

Notes: SCRES = supply chain resilience; SCP = supply chain performance; SCDO = SC disruption orientation; CC = communication and coordination; ITC = information technology; Pro = process capability; Col = collaboration; SF = strategic focus; Hum = human resource capability

Source: Authors’ own work

For common method variance, we used the Harman single factor method and found 30% variance for a single factor, which is sufficiently below the 50% threshold (Eichhorn, 2014; Podsakoff and Organ, 1986). In addition to Harman’s single factor method, we also used common latent factor to test for common method variance. The calculated common method variance was 23%, which is considerably below the threshold of 50% (Eichhorn, 2014). In addition, there is no indication of a high correlation between factors. Finally, for discriminant validity, the heterotrait-monotrait ratio of correlations was conducted, which is provided in Table 5. None of the correlations exceed 0.9, and the VIF values also are quite below the threshold of 5 (max = 2.8).

The proposed conceptual model was tested with structural equation modeling by using AMOS 27 software. Table 6 and Figure 4 present the results, and the results support a good fit for the model (chi square = 528.7, CFI = 0.947, IFI = 0.947 and RMSEA = 0.045).

H1 examines the relationship between strategic focus and SCDO. The results support the hypothesized positive relationship, confirming that higher strategic focus results in higher supply chain resilience capabilities.
SCDO (H1: standardized regression weight = 0.382). H2 evaluates the relationship between SCDO and process capability. The results support a strong positive relationship, confirming that higher SCDO results in higher process capability (H2: standardized regression weight = 0.587). Moreover, H3 assesses the relationship between SCDO and communication and coordination capability (H3: standardized regression weight = 0.685). H4 evaluates the relationship between SCDO and collaboration capability. The results support a positive relationship, affirming that higher SCDO results in higher collaboration capability (H4: standardized regression weight = 0.602). Furthermore, H5 investigates the relationship between SCDO and human resource capability. The results support the hypothesized positive relationship, asserting that higher SCDO
results in higher human resource capability ($H5$: standardized regression weight $= 0.770$). $H6$ evaluates the relationship between SCDO and information technology capability. The results support the hypothesized positive relationship, verifying that higher SCDO results in higher information technology capability. ($H6$: standardized regression weight $= 0.757$). In addition, $H7$ examines the relationship between process capabilities and resilience capabilities. The results support the hypothesized positive relationship, validating that higher process capability results in higher resilience ($H7$: standardized regression weight $= 0.130$).

$H8$ examines the relationship between communication and coordination capabilities and resilience capabilities. The results support the hypothesized positive relationship, verifying that higher communication and coordination capability results in higher resilience ($H8$: standardized regression weight $= 0.216$). $H9$ evaluates the relationship between collaboration capabilities and resilience capabilities. The results support the hypothesized positive relationship, affirming that higher process capability results in higher resilience ($H9$: standardized regression weight $= 0.125$). $H10$ assesses the relationship between human resource capabilities and resilience capabilities. The results support the hypothesized positive relationship that higher human resource capability results in higher resilience ($H10$: standardized regression weight $= 0.165$).

$H11$ assesses the relationship between information technology capabilities and resilience capabilities. The results support the hypothesized positive relationship that higher IT capabilities results in higher resilience ($H11$: standardized regression weight $= 0.148$). $H12$ investigates the relationship between resilience outcomes and SC performance. The results support the hypothesized positive relationship, asserting that higher resilience results in higher SC performance ($H12$: standardized regression weight $= 0.478$).

4. Discussion

In this research, we built a conceptual model of the antecedents and capabilities common to supply, operations and logistics as related to SCRES. While the literature provided a general overview of capabilities linked to SCRES, it felt short in identifying the specific capabilities common to supply, operations and logistics that impact SCRES. Therefore, qualitative research was undertaken to fill in the gaps and refine the model (Figure 1). A total of 51 interviews were conducted to uncover capabilities common to supply, operations and logistics functions that contribute to improving SCRES capabilities. Finally, the model was empirically investigated for managerial and theoretical insights. In this section, we discuss how our findings address our research goals and relate to past research.

Our major goal was to build a model of SCRES and then refine it in the automotive industry focused on supply, logistics and operations capabilities. The literature provided several different perspectives on understanding SCRES (Ali and Gölgeci, 2019; Ali et al., 2017; Han et al., 2020; Pettit et al., 2010; Pettit et al., 2013). However, the literature does not address the relative importance of capabilities on SCRES in idiosyncratic contexts (Kamalahmadi and Parast, 2016). This research extends the past research by identifying capabilities unique to the automotive SC, namely, process, communication and coordination, human resources, collaboration and IT capabilities. While all five capabilities have been discussed in the past literature in a general context (Scholten and Schilder, 2015; Gu et al., 2021), this research, through the quotes from Appendix 2 coupled with the items used in this research (Appendix 3), provides insights into the mechanisms of these capabilities within the context of the automotive industry. A common aspect of these capabilities is that, because of the complexity of the automotive SC, these capabilities enable flexibility, quick decision-making and skipping hierarchies. An
insightful quote from Josef at AutoTechSupplier provides further triangulation for the need for flexibility:

You have to be flexible, and you need short coordination paths because often you have to make decisions very quickly, and when you have to go through several hierarchies, it is difficult.

While this was a stated goal of the research, because of the qualitative nature of the first study, a new concept of strategic focus was uncovered. Organizations make choices by investing resources in options that support SC strategy at strategic, operational and/or tactical (Gunasekaran et al., 2001) for the right balance of efficiency and responsiveness in SCs (Fisher, 1997). Strategic focus is particularly important in automotive SCs because the industry is characterized by a high level of investment in research and development and the significant costs associated with the manufacture and marketing of vehicles. Therefore, efficiency-driven initiatives such as JIT, lean manufacturing and high productivity (Goshime et al., 2019) are prioritized. However, while talking about SCRES, when managers alluded to the strategy of the company, it emerged that focus on customer and brand led to a company investing more in SCRES capabilities, while a focus on cost (such as production optimization) led to decisions that compromised flexibility and responsiveness of the company and hence the ability to react during times of disruptions (Sebastiao and Golicic, 2008). This is consistent with the debate in the extant literature on the trade-offs between lean and resiliency (Ivanov et al., 2014). Our empirical testing provides support for the conjecture that higher strategic focus results in a higher supply SCDO.

The research aimed to quantitatively test the impact of SCDO on capabilities selected based on qualitative research. Consistent with Ambulkar et al. (2015) and Bode et al. (2011), we found that SC disruption-oriented firms require the ability to reconfigure resources and proactively build specific capabilities, enhancing SCRES. These findings merge two streams of research: one that is focused on the identification of capabilities linked to SCRES (Ambulkar et al., 2015; Blackhurst et al., 2011; Jüttner and Maklan, 2011; Scholten and Schilder, 2015) and the other that investigates the relationship between SCDO and SCRES (Ambulkar et al., 2015; Yu et al., 2019) by identifying and testing the impacts of five specific SCRES capabilities.

One of the research goals of this study was to prioritize the most vital capabilities linked to SCRES in automotive and other similar manufacturing firms. Similar to Bode et al. (2011), who found that SCDO impacts both buffering and bridging disruption-response strategies, we found SCDO impacted all the capabilities investigated in this research. Our research found that the impact of SCDO on all capabilities was somewhat equal. However, we found that not all the capabilities impacted SCRES similarly. More specifically, communication and coordination capability showed the strongest relationship to SCRES followed by human resource and IT capabilities. Process and collaboration capabilities, while significant, showed the weakest link to SCRES. This result is reflective of the unique nature of disruptions. While process capabilities are important for the regular functioning of an automotive and other manufacturing enterprises, communication and coordination are particularly critical during times of disruption as they enable quick response. As automotive and other manufacturing firms have complex SCs, the systems view suggests that capabilities across multiple entities in the system are needed to react to disruptions (Adobor, 2019). However, the entities need to prioritize the investment into capabilities to generate an optimum response for the system.

An important goal of this research was to empirically test the relationship between SCRES and SC performance. The findings reveal that SCRES impacts SC performance (relative to competitors) and sales, a measure of organizational performance. This is contrary to the literature that there is an inherent trade-off between financial performance (efficiency) and resilience performance (Dynes et al., 2007; Ruiz-Benitez et al., 2018). Spiegler et al. (2012) mention the trade-off between SCRES and cost (such as that of flexibility) but also acknowledge that other cost elements that are difficult to measure (such as poor customer service or loss of control) may rise due to lack of SCRES. From an ecological perspective, in the specific context of coupled infrastructure systems, Homayounfar et al. (2018) and Homayounfar et al. (2022) pointed out the trade-offs between resilience and robustness, and between resilience and performance respectively. However, this result is consistent with the RBV that argues that as a company acquires resources or combines these resources into capabilities and develops a specific set of capabilities to achieve higher financial performance (Barney, 1991, 1995). Overall, this research extends the current understanding of SCRES by addressing the call for research in SCRES that SCRES is unique to specific contexts and bridges the gap between research that is too broad or too narrow (Kamalalmadi and Parast, 2016).

5. Implications

5.1 Theoretical contributions from qualitative and quantitative research
In developing, refining, and using qualitative research and empirically testing a model of SCRES, we make six theoretical contributions.

First, the literature review and field study identified common capabilities that are most important for SCRES. Next, a qualitative study was undertaken determine key capabilities of supply, operations and logistics capabilities most relevant to SCRES. Following capabilities emerged: process, communication and coordination, human resources, collaboration and IT capabilities. The theoretical implication of this finding is the empirically validated delineation of the most relevant capabilities from a wide and diverse pool of capabilities linked to SCRES.

Second, a new concept of strategic focus linked to SCRES emerged in the qualitative study and was tested in the quantitative study. This finding is noteworthy as it is the result of a mixed method design – qualitative research for discovery and operationalization of the construct and quantitative research for empirical testing.

Third, we theorized that SC disruption-oriented firms invest in proactively building unique combinations of resources to enhance SCRES. This finding is theoretically relevant in that it provides empirical support for the importance of building resilience capabilities and their relations to disruption orientation. In addition, this is also one of the few empirical studies that provide empirical support for the argument that the
Supply chain resilience capabilities
Ila Manoj, Michael Herberger and Saban Adana

awareness and consciousness of disruptions (SCDO) of an organization impacts SCRES.

Fourth, this research advances the theory of SCRES by going beyond providing a list of capabilities to identify the relative importance of identified capabilities. The grounded theory helped to uncover and provide detailed descriptions of capabilities, and the quantitative research allowed empirical testing to provide results that are generalizable to a wider manufacturing context. The capabilities in the order of significance are communication and coordination (strongest), human resource and IT capabilities and process and collaboration (weakest) capabilities. This finding is built upon the unique strength of mixed method approach to provide a more holistic understanding of a phenomenon than a single approach method (Creswell, 2014).

Fifth, an important theoretical contribution of this research is that it not only theorizes the link between SCRES and SC performance, and SCRES and sales, but also provides empirical evidence for primarily conceptual research in the field (Ali et al., 2017; Hohenstein et al., 2015).

The lack of the use of multi-method research and the missing link between qualitative research and the development of formal theory have long been identified as limitations of research in the discipline. This research used qualitative research to not only refine a conceptual model based on extant literature but also help fill in the critical gaps (related to the identification of most relevant capabilities) and inform the development of items and the development of formal theory for hypothesis testing. This three-step methodology contributes to our goal of holistic understanding of SCRES in automotive and other manufacturing industries.

5.2 Managerial contributions
Managerial time and resources are seldom unconstrained. This research informs managerial decision-making by identifying specific capabilities common to supply, logistics and operations that impact SCRES. While qualitative research led to the identification of five major capabilities, empirical retesting revealed three of the five to be of consequence. This should help managers better allocate resources to only significant capabilities. Managers can further fine-tune the allocation of resources by looking at the strength of the relationship between individual capabilities and SCRES.

It is important to note that the capabilities do not act in isolation. Consistent with the notion of interdependence in systems theory, we found that there is dependence between different capabilities and processes used to enable these capabilities. For example, IT capability will impact communication, coordination and collaboration capabilities. Furthermore, as is evident from the quotes managers and therefore systems react to the outcomes to change inputs and processes to react to disruptions and become more resilient in the future. While these notions of interdependence and feedback are difficult to capture in a quantitative study that captures a snapshot, these notions were quite evident in the qualitative research.

Since the operationalization of capabilities borrowed heavily from the qualitative study built upon what managers thought to be critical for SCRES, the items themselves provide a good template for specific, actionable items. A quick search of literature could provide over 50 items to measure a capability. However, our operationalizations are specific to disruptions and, thus, valuable for managerial decision-making. For instance, the items “Our employees know their responsibilities in times of disruptions” and “Our employees know the actions to be taken in times of disruptions” provide managers with specific, actionable tasks of ensuring that employees know their responsibilities and the actions that could be taken during times of disruption. These items can provide insights for managers to prepare SCs and for employees to effectively manage SC disruptions.

It is imperative that managers invest in capabilities based on their unique context. For example, Dohmen et al. (2022, p. 18) found that in the specific case of a food manufacturer “decision-making actions related to the use of information in the firm’s supply chain planning process were observed to have a more positive impact on service and inventory performance than actions related to resource reconfiguration”. Similarly, information processing capability was found to be important in SCRES in the specific case of a Chinese cross-border e-commerce company (Wang et al., 2021). Overall, this research provides unique and specific insights in automotive industry and industries with similar characteristics.

Some relationships tested in this research are not novel but provide insights that could impact managerial decision-making. For instance, this research reiterated that the role of disruption orientation is in developing capabilities. It also supports that SCRES is critical to SC performance, which, in turn, drives organizational performance.

Given the increasingly disruptive nature of the current business environment, as evidenced by COVID-19, firms that develop appropriate capabilities to achieve higher resilience will have strong positions to not only survive but also benefit from SC disruptions. For instance, Pfizer, because of its move to develop and provide an effective vaccine, had a 44% increase in US revenue for the first quarter of 2021 (yahoofinance, 2021). This research, by providing evidence for importance of SCRES and suggesting relevant strategies, contributes to our goal of informing sound managerial decision-making based on empirical data.

5.3 Conclusions, limitations and future research
This research is based on a literature review, qualitative research and quantitative analysis to develop and validate a conceptual model of SCRES. It demonstrates the importance of specific capabilities in improving SCRES across supply, operations and logistics functions. We identified five key capabilities most relevant linked to SCRES (namely, process, communication and coordination, collaboration, human resources and IT capabilities) and their relative impact on SCRES in the context of automotive and other manufacturing SCs. This study is one of the few to establish linkages between specific capabilities and SCRES, providing actionable insights for managers to improve SCRES. The findings of this study can help managers to identify areas where they need to focus their attention and allocate resources effectively to build more resilient SCs. Furthermore, the study revealed that strategic focus and disruption orientation lead to higher investment in SCRES capabilities, whereas a focus on cost leads to decisions
that compromise the flexibility and responsiveness of the company.

As with all research, this study is not without limitations. First, it is necessary to realize that organizational capabilities and SCRES concepts are quite broad and that capturing all of them in one study is impossible. Thus, future studies can concentrate on identifying additional capabilities and their impacts on SCRES.

Second, the process to generate these capabilities is not quite established in the literature, and future research can help us better understand how these capabilities can be generated in different industries. One research question in that direction would be how do supply, logistics and operations capabilities are developed in the automotive industry? Are there differences to the food industry?

Moreover, we did not differentiate on the type of disruptions that might have implications for a specific capability. Not only the pandemic but also many high-profile cyber-attacks have shown that disruptions could have different characteristics and SC implications. Future research can investigate the differences between different SC disruptions, e.g. between a natural disaster and a man-made disruption, such as a cyber-attack.

Research in SCRES does not yet fully consider the differences, although it is comprehensible that SCs resilient to earthquakes are not automatically resilient to cyber incidents. Therefore, the aspect of resilience of “of what”, “to what”, “for whom” (Carpenter et al., 2001; Cutter, 2016) and “over what timeframe” must be considered in our discipline (Hellgott, 2018; Oliver, 2016).

Although we gathered the data on firm size, we did not look at the potential difference between SMEs and large companies in leveraging these capabilities to achieve resilience. Future research can question whether all capabilities equally impact SMEs versus large companies. Finally, future studies could also investigate whether there would be differences across divergent cultures on the weights of the capabilities or whether culture would have any effect on the aforementioned relationships.

References


Supplement 2023/01: Supply chain resilience capabilities

Ila Mamuj, Michael Herberger and Saban Adana


Further reading


Appendix 1

Table A1 Overview of participating companies

<table>
<thead>
<tr>
<th>Company</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AutoPartsSupplier</td>
<td>International manufacturer and supplier to automotive and engineering industries with presence in over 100 countries; revenue over €5bn</td>
</tr>
<tr>
<td>AutoManPartner</td>
<td>Automotive supplier with more than 250 production sites in 20 countries; revenue over €25bn</td>
</tr>
<tr>
<td>AutoTechSupplier</td>
<td>International technology supplier to automotive and home appliance industries with presence in over 45 countries; revenue over €10bn</td>
</tr>
<tr>
<td>AutoMan</td>
<td>Automotive manufacturer; revenue over €10bn</td>
</tr>
<tr>
<td>VehicleMan</td>
<td>Manufacturer of agricultural machinery; revenue over €300m</td>
</tr>
</tbody>
</table>

Source: Authors’ own work

Appendix 2

Table A2 Exemplar quotes for constructs used in quantitative study

<table>
<thead>
<tr>
<th>Construct</th>
<th>Exemplar (power and proof) quotes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategic focus</td>
<td>“But right from the start, especially in our product area, we have concentrated on where we are competitive. So we have carved out the niches a bit. We don’t want to fight based on price, but rather use these areas where the price pressure is not so great because the competitors are not interested in joining in”. Hermann, AutoPartsSupplier</td>
</tr>
<tr>
<td>Process capability</td>
<td>“Your process needs to be clearly standardized and if you have deviations, you need to react to them. If they have no standards or clear rules, you cannot organize any deviation management”. (Sebastian, AutoMan)</td>
</tr>
<tr>
<td>Communication and coordination capability</td>
<td>“The initiative was to bring information to the employees. Open communication was fruitful. We brought the broad knowledge to the table in smaller groups and talked about managing this (disruption) operationally. It was a permeable situation among the board, management, and employees and a success factor in this difficult situation”. (Richard, AutoTechSupplier)</td>
</tr>
<tr>
<td>Human resource capability</td>
<td>“Experience has helped us well through the crisis”. (Gerald, AutoTechSupplier)</td>
</tr>
<tr>
<td>Collaboration capability</td>
<td>“We benefit from the fact that we have very experienced, long-standing employees who know the processes very well”. (Zacharias, AutoMan)</td>
</tr>
<tr>
<td>Information technology capability</td>
<td>“All the players involved must be really well connected and communicate systematically. If there is a deviation, that person passes it on to the people places that are affected by it”. (Albert, VehicleMan)</td>
</tr>
</tbody>
</table>

Source: Authors’ own work
### Appendix 3

Table A3  | Items and source
--- | ---
**Construct** | **Source and question** | **SD** | **λ** | **α**
--- | --- | --- | --- | ---
**Strategic focus** | Qualitative study. (Froehle and Roth, 2004; Roth et al., 2008) To what extent does your organization/business unit pursue the following strategies to stay competitive? | 0.769
SF1 | Efficiency improvements in production | 1.066 | 0.771
SF2 | Systematic development of the brand name | 1.086 | 0.814
SF3 | Systematic targeting of market segments or niche markets | 1.073 | 0.872
**Supply chain disruption orientation** | Adapted from Bode et al. (2011). Please indicate to what extent you agree with the following statements about the supply chain disruption orientation of your organization/business unit. | 0.759
SCDO1 | Supply chain disruptions show us where we can improve | 0.896 | 0.801
SCDO2 | We recognize that supply chain disruptions are always looming | 0.904 | 0.815
SCDO3 | We feel the need to be alert for possible supply chain disruptions at all times. | 0.989 | 0.846
SCDO4 | We think a lot about how a supply chain disruption could have been avoided | 0.985 | 0.746
**Process capabilities** | Adapted from Srinivasan and Swink (2018) Please think about the process capabilities in your organization/business unit. Please indicate to what extent you agree with the following statements. | 0.773
PC1 | We can create new supply chain processes quickly | 1.098 | 0.840
PC2 | Our employees know their responsibilities in times of disruptions | 1.018 | 0.819
PC3 | Our employees know the actions to be taken in times of disruptions | 0.995 | 0.806
**Communication and coordination** | Adapted from Gligor and Holcomb (2012) and Chen and Paulraj (2004) and Wieland and Wallenburg (2013). Please think about your communication and coordination capabilities with your key partners in the supply chain. Key partners are characterized by high dependence between you and suppliers/customers. Please indicate to what extent you agree with the following statements. | 0.811
CoCo 1 | Our suppliers and our organization provide each other with information that might help us | 0.917 | 0.874
CoCo 2 | Exchange of information with customers takes place in a timely manner | 1.009 | 0.847
CoCo 3 | Exchange of information with suppliers takes place in a timely manner | 0.988 | 0.835
**Collaboration** | Adapted from Fawcett et al. (2011) and Scholten and Schilder (2015) Please think about your collaboration capabilities with your key partners in the supply chain. Please indicate to what extent you agree with the following statements. | 0.744
Co1 | No matter who is at fault, problems are joint responsibilities between our customers and our organization | 1.136 | 0.890
Co2 | We do not mind owing each other favors with customers | 1.100 | 0.876
Co3 | We do not mind owing each other favors with suppliers | 1.140 | 0.771
**Human resources** | Adapted from Polyviou et al. (2020), and Fischer and Pollock (2004) and Qualitative Study Please think about the human resource capabilities in your organization/business unit. Please indicate to what extent you agree with the following statements. | 0.752
HR1 | We have longtime employees with experience in disruption management | 1.000 | 0.843
HR2 | We train our employees in disruption management | 1.021 | 0.748
HR3 | Our management and staff trust each other in times of disruptions | 0.965 | 0.858

(continued)
### Table A3

<table>
<thead>
<tr>
<th>Construct</th>
<th>Source and question</th>
<th>SD</th>
<th>λ</th>
<th>α</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Information technology</strong></td>
<td>Adapted from Fawcett et al. (2011)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IT1</td>
<td>Please think about the information technology capabilities in your organization/business unit. Please indicate to what extent you agree with the following statements.</td>
<td>1.006</td>
<td>0.870</td>
<td></td>
</tr>
<tr>
<td>IT2</td>
<td>Our internal IT systems enable our employees to quickly respond in times of disruptions</td>
<td>1.060</td>
<td>0.899</td>
<td></td>
</tr>
<tr>
<td>IT3</td>
<td>Our IT systems on the customer side enable a quick response in times of disruptions</td>
<td>1.053</td>
<td>0.897</td>
<td></td>
</tr>
<tr>
<td><strong>Supply chain resilience (SCRES)</strong></td>
<td>Adapted from Chowdhury and Quaddus (2017)</td>
<td></td>
<td></td>
<td>0.880</td>
</tr>
<tr>
<td>SCRES1</td>
<td>We can recover from the crisis with the least cost</td>
<td>1.025</td>
<td>0.845</td>
<td></td>
</tr>
<tr>
<td>SCRES2</td>
<td>We can undertake adequate response to a crisis</td>
<td>1.078</td>
<td>0.852</td>
<td></td>
</tr>
<tr>
<td>SCRES3</td>
<td>We have enough resources to respond during a crisis</td>
<td>1.112</td>
<td>0.841</td>
<td></td>
</tr>
<tr>
<td>SCRES4</td>
<td>We have response teams in place for mitigating crisis</td>
<td>1.156</td>
<td>0.844</td>
<td></td>
</tr>
<tr>
<td>SCRES5</td>
<td>We have strong security systems to protect against man made crisis</td>
<td>1.122</td>
<td>0.860</td>
<td></td>
</tr>
<tr>
<td><strong>Supply chain performance</strong></td>
<td>Adapted from Gunasekaran et al. (2004) and Shepherd and Günter (2011)</td>
<td></td>
<td></td>
<td>0.819</td>
</tr>
<tr>
<td>SCP1</td>
<td>Compared with your major competitors, your cash-to-cash cycle times are</td>
<td>0.944</td>
<td>0.799</td>
<td></td>
</tr>
<tr>
<td>SCP2</td>
<td>Compared with your major competitors, your delivery performance versus commit date is</td>
<td>0.949</td>
<td>0.899</td>
<td></td>
</tr>
<tr>
<td>SCP3</td>
<td>Compared with your major competitors, your quoted order lead times are</td>
<td>0.957</td>
<td>0.882</td>
<td></td>
</tr>
<tr>
<td>SCP4</td>
<td>Compared with your major competitors, your overall inventory turnover is</td>
<td>0.956</td>
<td>0.764</td>
<td></td>
</tr>
</tbody>
</table>

Source: Authors’ own work

### References


Roth, A.V. (2008), *Handbook of metrics for research in operations management: Multi-item measurement scales and objective items*, Sage.


Appendix 4

Table A4 Descriptive statistics for quantitative study

<table>
<thead>
<tr>
<th>Item</th>
<th>Average</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of disruptive events affecting your supply chain in the current year</td>
<td>7.73</td>
<td>0</td>
<td>120</td>
</tr>
<tr>
<td>Total financial cost of these disruptions in the current year</td>
<td>1 Million</td>
<td>0</td>
<td>8 Million</td>
</tr>
<tr>
<td>Break-down of the frequency of causes of disruptions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[Suppliers/In-bound logistics (e.g. transport problems or product quality)]</td>
<td>28%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal organizational problems (e.g. human errors, technical failures, quality issues)</td>
<td>26%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[Customers/Out-bound logistics (e.g. transport problems, fluctuations in demand)]</td>
<td>21%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[External Risks (e.g. natural disasters, crime, legislation)]</td>
<td>25%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Please describe a major disruption from the last year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>For the major disruption you described earlier, how long did it take to restore normal operations and functionality?</td>
<td>31.3 days</td>
<td>0</td>
<td>365</td>
</tr>
<tr>
<td>Number of direct (1st tier) suppliers</td>
<td>38</td>
<td>0</td>
<td>1100</td>
</tr>
<tr>
<td>Number of direct (1st tier) customers</td>
<td>5</td>
<td>0</td>
<td>1000</td>
</tr>
<tr>
<td>Your customers are: [companies (B2B)]</td>
<td>48%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Your customers are: [end consumers (B2C)]</td>
<td>52%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total number of employees in your company:</td>
<td>11,000</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Total number of employees in your organization/business unit:</td>
<td>1031</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Company-revenue in the past financial year:</td>
<td>78,500,000</td>
<td>5 million</td>
<td>1 billion</td>
</tr>
<tr>
<td>Revenue of the organization/business unit in the past financial year:</td>
<td>2,400,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Please indicate the extent of vertical integration your organization/business unit has in comparison to your competitors.</td>
<td>18% less vertical</td>
<td>%30 more vertical integration</td>
<td>%52 same vertical integration</td>
</tr>
</tbody>
</table>

In which industry does your company operate?
[Aviation/Defence] 5%
[Automotive Industry] 10%
[Chemical industry] 2%
[Consumer goods industry] 15%
[Electronic engineering/optical and mechanical devices] 14%
[Construction industry/Engineering] 5%
[Food] 10%
[Industrial machinery/tool construction] 9%
[Metalworking industry] 6%
[Oil/Gas/Minerals] 4%
[Paper/packaging and related products] 5%
[Pharmaceutical industry/Health care] 5%
[Transport/Logistics] 10%
How long has your company been operating in the selected area? 41 years
How many years of experience in supply chain management do you have? 10 years
Where are you located? 40% Headquarters/ 60% Subsidiary

Source: Authors’ own work

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